XVI. *On the Development and Extinction of regular doubly refracting Structures in the Crystalline Lenses of Animals after Death.* By *Sir* David Brewster, *K.H. LL.D. F.R.S. &c. &c.*

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SINCE the year 1816, when I communicated to the Royal Society an account of the doubly refracting structures which exist in the crystalline lenses of fishes and other animals, I have examined a great variety of recent lenses, with the view of ascertaining the origin of these structures, the order of their succession in different lenses, and the purpose which they answered in the animal œconomy. Although I had found that in the lenses of the cod, the salmon, the haddock, the frog-fish, the skate, and several other fishes there were three structures, the innermost of which had negative double refraction, the next *positive*, and the outermost negative double refraction, yet in the lenses of animals the greatest discrepancies presented themselves. In every case, however, excepting one, I have found the central structure in all quadrupeds* to be positive, while it is always negative in fishes when there are three structures, but this positive structure sometimes existed alone, with faint traces of a negative structure; sometimes it was followed by another *positive* structure, separated from the first by a black neutral circle, in which the double refraction disappeared. Sometimes these two positive structures were succeeded by an external negative structure. Sometimes the central and external positive structures were separated by a negative structure, and at other times the lens exhibited *four* structures, a negative and a positive one alternating. As these discrepancies appeared in the lenses of animals of the same species, I conceived that they were owing to differences of age or sex, or to some change in the health of the animal. I was therefore led to make new observations in reference to these probabilities, and to observe the phenomena with additional attention when the structure differed from that which was most common. In these observations I sometimes noticed in the dark or neutral line, which separated two positive structures, something like a trace of an intervening structure, which was either about to disappear, or about to be developed. This conjecture was confirmed by observations on the lenses of a cow eleven years old.

The lenses after being carefully taken out, were freed from the adhering portions of the vitreous humour by the gentle application of blotting paper, so as not to disturb their internal structure. The lenses were elliptical. Their longest diameter was 0·774 inch, their shortest diameter 0·747 inch, and their thickness 0·513 of an inch. The first lens which I exposed to polarized light was in the highest perfection, and the symmetry of the optical figure unusually beautiful. I have represented it in

* Excepting the hare. See Phil. Trans. 1836, p. 37.

Plate XV. fig. 1., in which only two structures, or two series of positive sectors, are visible*. The lens was now a day old, and there seemed to be a faint light within the two black rings, especially in the outer one, which was either the remains of an old, or the germ of a new structure. If this were the case, then the anomalous combination of two positive structures would be converted into a combination of four structures, in which a negative and a positive one alternated.

On the following day I prepared the other lens with the same care, and found my conjecture completely verified. In the middle black ring, which was distinctly brownish in the first lens, the negative structure had evidently commenced at one part, and the colour of the whole ring was a brighter brown than in the first lens. In the outer black ring another negative structure had also appeared, and had advanced considerably upon the positive structure. These phenomena I have represented in fig. 2., where the four structures are distinctly seen, the second being a faint blue of the first order. On the third day the two new structures had become more prominent. The structure No. 2, now a pale white of the first order, was completely developed, having encroached upon and almost obliterated the third structure. The structure No. 4, which was not in existence on the first day, had now the maximum tint, namely a bright white of the first order. On the fourth day the structures No. 2 and 4, which at first were not in existence, are now the structures with the maximum tints, and No. 3, which had the maximum tint, is now almost obliterated, a little faint brown light remaining in one of the quadrants.

On the fifth day the four sectors of the inner structure No. 1, have almost disappeared. No. 3 has disappeared entirely, and No. 2, which is almost the only polarizing structure, exhibits a more intense white of the first order than appeared in any part of the lens. The ring No. 2 divides the radius of the lens equally.

On the sixth day the structure No. 2 was still bright and uniform, but the polarized light had disappeared from every other part of the lens.

On the seventh day the lens, which was always placed in water, burst its capsule, and there was no longer any trace of distinct polarizing structures.

My next observations were made on the lenses of a cow nearly twenty years old. The following were the dimensions of the eye and the lenses.

	Inch.
Diameter of eyeball	1·66
Chord of the cornea (largest)	1·30
Chord of the cornea (shortest)	1·02
Longest diameter of lens	0·827
Shortest diameter of lens	0·793
Thickness of lens	0·50

* Upon referring to my earlier observations, I find that in both the lenses of an ox there was only one structure which was a positive one, and which had not yet divided itself into two structures, as in that of the cow under consideration. There was the appearance of a black space near the margin of the lens, but the polarized light both within and without that black ring was positive.

In the lens of another ox, and of a bull, I found the *positive* structure separated into two positive structures by a distinct black ring, while an external negative structure was clearly developed.

Fig. 1.

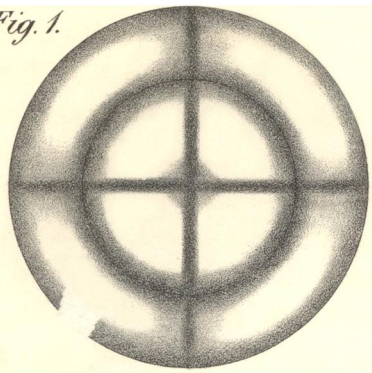


Fig. 2.

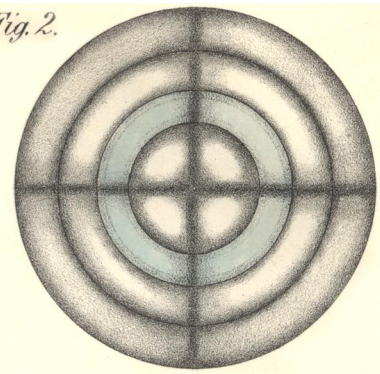


Fig. 3.

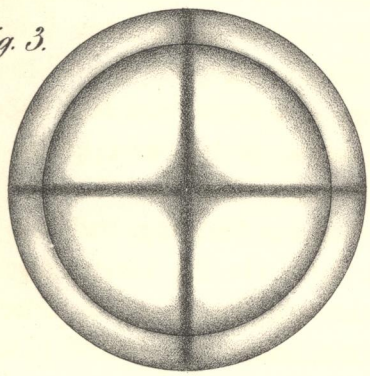


Fig. 4.

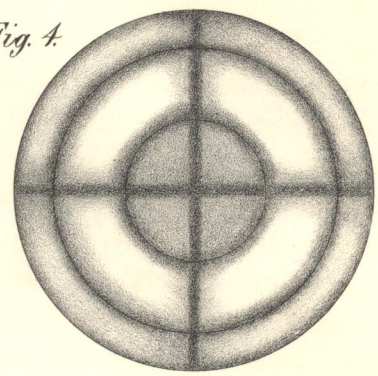


Fig. 5.

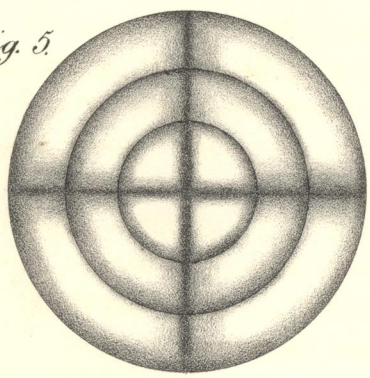


Fig. 6.

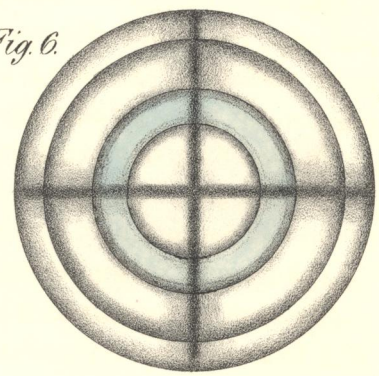


Fig. 7.

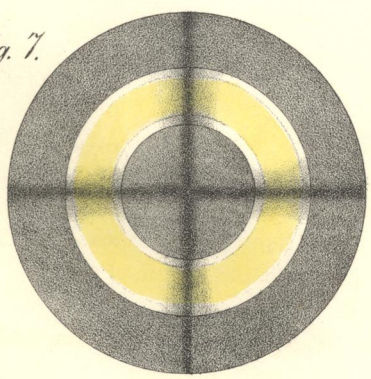
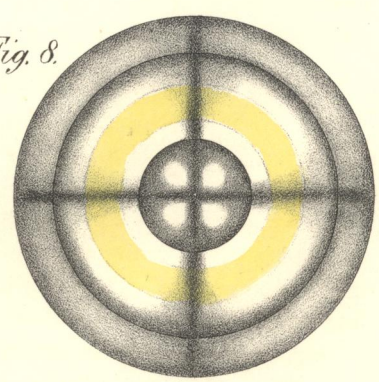


Fig. 8.



J. Basire, lith.

Both the lenses of the cow exhibited when taken out of the eye four beautiful structures, in which the positive and negative structures alternate. The first and fourth were very faint, being the palest white of the first order. The third was also faint, but the second was both bright and large, and its tint was a *brilliant yellow* of the first order. After lying four days in water the lenses swelled so much that their dimensions were as follows:

	Inch.
Diameter of one lens	0·807
Diameter of the other	0·793
Thickness of the first	0·647
Thickness of the second	0·620

The lenses were still transparent, and the tint of the structure No. 2 had risen to an *orange red* of the first order.

Having experienced great difficulty in the course of the preceding experiments in preserving the capsule of the lens transparent for several days, I made trial of various fluids, but found distilled water more suited to my purpose than any other. I therefore began a regular course of observations on the crystalline lens of the sheep when placed in distilled water, which have afforded me very satisfactory results.

The lens of a sheep a year and a quarter old, when newly taken out of the eye, exhibited in the distinctest manner only one structure, with slight traces of an external one. This structure was *positive*, and occupied almost the whole of the lens, as shown in fig. 3. The traces of an external structure, when carefully examined, showed it to be negative. On the following day this lens burst in the direction of the three septa.

In the lenses of another sheep I found two structures like the preceding, but with this difference, that the external negative structure was more developed, as in fig. 4. On the following day this negative structure had extended itself inwards, but in consequence of an accident the lenses burst their capsule.

In the lenses of another Cheviot sheep, where the external negative structure had just begun to appear, the wide positive structure shown in fig. 3 had just begun to separate itself by a dark neutral line, which was seen only in one of its four sectors, and which divided that sector into two.

In another Cheviot sheep the principal positive structure had distinctly divided itself into two positive structures, separated by a dark neutral ring, as shown in fig. 5. The same appearance was shown in the other lens; and I have found it a very common structure in the lenses of sheep at that age when they are killed for the table.

When this division of the principal structure takes place the central one is at first faint, and the other a bright white of the first order, as in fig. 4. It becomes, however, brighter and brighter till it nearly rivals the other in the intensity of its polarized tint, as in fig. 5, when another change begins to show itself.

This change, similar to that which I have described in the lens of the cow, arises from the absorption of distilled water by the capsule of the lens. It first shows itself

by the appearance of a brown tint in the dark neutral ring which separated the two positive structures. In the middle of the brownish black ring a trace of faint blueish light appears, generally in one of the sectors only, but gradually extends itself into a blue ring, which has negative double refraction and which is separated by distinctly formed black rings from the two positive structures, between which it lies. This state of the polarizing structure is shown in fig. 6, which is nearly the same as in the lens of the cow.

The structure No. 1, beginning at the centre, was pretty bright, but No. 3 was much more so, and No. 4 very faint, though perfectly distinct.

On the second day the blue ring No. 2 was much enlarged, and had encroached greatly on the brightest structure No. 3, having reduced it both in breadth and intensity. No. 4 has also extended itself at the expense of No. 3.

On the third day the new structure No. 2 had become the brightest of all. No. 4 had increased also, whilst No. 1 had become smaller and fainter, and No. 3 was wholly obliterated.

In another pair of lenses one of them burst at this stage of the development of the polarizing structures, while in the other the effect was singularly fine. No. 3 was wholly, and No. 1 nearly obliterated; while the two new structures, which had no existence at first, were the only ones that remained. The new negative structure No. 2 consisted of four beautiful blue sectors of polarized light; but in consequence of the great absorption of distilled water, and the consequent distension of the lens, it soon burst.

I have already remarked that only one case has occurred in the course of my experiments in which the central structure of the lenses of quadrupeds was negative, as in fishes. In this case, however, the centre of the lens had its structure affected by some change in the condition of the fibres at their union in the three septa, which were not only distinctly seen, but had the polarizing structure clearly related to them. The polarized light filled up each of the three angles of 120° which lay between the three septa, and the intensity of the light was a maximum close to the three septa. Hence it is evident that the central *negative* structure was the result of an induration of the lens related to the septa, and had obliterated the *positive* structure which would otherwise have existed there.

In examining the lenses of the *horse* I have observed the progressive development of its three structures as the animal advanced in age, and the extinction of all of them but one when the age of the animal was great.

In both the lenses of a young horse three years old I found only one positive structure.

In both the lenses of a horse whose age was unknown, I observed three structures beautifully developed. The central ones, which were extremely distinct and more beautiful in form and more intensely luminous than in any other quadruped which I had examined, were *positive*, the next structure *negative*, and the external one *positive*.

In the lens of another horse, whose age was also unknown to me, the remains of three structures were visible; but the two positive ones, namely, the central and external structures, had just disappeared, but were not encroached upon by the intermediate negative one. They were therefore black when seen by polarized light, as shown in fig. 7, while the remaining *negative* one was of the most brilliant yellow colour.

In the lenses of a third horse, probably of an intermediate age, I found a structure intermediate between that of the two preceding ones. The following were the dimensions of its lenses.

	First Lens. inch.	Second Lens. inch.
Longest diameter	0·827	0·820
Shortest diameter	0·793	0·793
Thickness	Not measured	0·500

The first lens having been carefully prepared and immersed in distilled water, exhibited the beautiful optical figure which is but imperfectly represented in fig. 8. The central sectors were *positive*, but faintly illuminated. The wide and brilliant yellow and white structure was *negative*, and the external structure, which had just begun to appear, was *positive*.

On the second day the black mass round the central sectors had enlarged itself, and become very black, having the form of a square lozenge. The *yellow* ring has risen in its tint to a *brilliant pink* yellow at the edges, the white ring within it having increased in width, and the white ring without it having diminished.

On the third day the diameter of the lens had increased to 0·86 in all directions, and its thickness from 0·50 to 0·717 of an inch. The coloured ring has not changed greatly.

On the fourth day the bright pink of the negative structure has risen to a bright blue, the pink and yellow being seen at its margin; and the external positive structure seems to be now conjoined with the blue negative structure, in consequence, no doubt, of the extension of the latter to the margin of the lens. The thickness of the lens was now upwards of 0·86, and the capsule came off, in consequence of which two of the blue sectors have become of a pale pink colour. The instant the capsule came off the lens shrunk in all its dimensions nearly the *tenth* of an inch.

The *second* lens on the *third* day gave exactly the optical figure shown in fig. 8, having been newly placed in distilled water; but the external ring seems to be slightly *negative*, like the yellow one. Its appearance was greyish and indistinct.

On the *fourth* day the yellow ring had risen to a *pale pink* of the first order, and the outer ring was *negative*, as on the preceding day.

On the *fifth* day the *pink ring* had increased in intensity, and the other structures remained the same as before.

On the *sixth* day the *pink* had risen to a very *bright blue*. The diameter of the

lens was now 0·867 of an inch, and its thickness 0·733, being an increase of 0·233 of an inch in thickness.

On the *seventh* day the capsule burst, and upon removing it and the soft pulp which formed about *one tenth* of an inch of the outer margin of the lens, the pink ring, with the white band both within and without it, and the black mass at the centre of the rectangular cross, were as distinct as ever. Hence it is manifest that the rise of the tint from *yellow* was not the effect of any expansive pressure produced by the swelling of the lens and the reaction of the capsule.

The descent of the tint from *bright blue* to pink was no doubt owing to the polarizing action of the extended capsule being withdrawn. In order to prove this I took the capsule, which is a tough and elastic membrane, and having stretched it, I found that it polarized, just before it tore, a white of the first order. Now the value of this tint is nearly equal to the difference between the values of the *pink* and *blue* of the second order of colours.

The preceding results throw much light on the physiology of the crystalline lens; and I shall have occasion, in a separate paper, to point out the conclusions to which they lead respecting the cause and cure of cataract.

Allerly by Melrose,
May 6th, 1837.